Name ________________________________

Investigating Common Descent: Formulating Explanations and Model

Background: Common Descent

This activity has extensive historical roots. Few question the idea that Charles Darwin's Origin of Species in 1859 produced a scientific revolution. Darwin proposed a number of ideas that included: organisms of different kinds descended from a common ancestor (common descent); species multiply over time (speciation); evolution occurs through gradual changes in a population (gradualism); and competition among species for limited resources leads to differential survival and reproduction (natural selection). This activity examines the theory of common descent.

The theory of common descent replaced a model of straight-line evolution with that of a branching model based on a single origin of life followed by a series of changes—branching—into different species.

Based on his observations during the voyage of the H.M.S. Beagle, Darwin concluded that three species of mockingbirds on the Galapagos Islands must have some connection to the single species of mockingbird on the South American mainland. Here is the intellectual connection between observations and explanation. A single species could produce multiple descendent species. Once this idea was realized, it was only a series of logical steps to the idea that all birds, all vertebrates, and so on, had common ancestors.

Common descent has become a conceptual backbone for biology. The idea has supporting evidence in comparative anatomy, comparative embryology, and biogeography. Recently, molecular biology has provided further support, as the students will discover in this activity.

Evidence consists of observations and data on which to base scientific explanations. Using evidence to understand interactions allows individuals to predict changes in natural and designed systems.

Background: Models

Models are tentative schemes or structures that correspond to real objects, events, or classes of events, and that have explanatory power. Models help scientists and engineers understand how things work. Models take many forms, including physical objects, plans, mental constructs, mathematical equations, and computer simulations.

Scientific explanations incorporate existing scientific knowledge and new evidence from observations, experiments, or models into internally consistent, logical statements. Different terms, such as "hypothesis," "model," "law," "principle," and "theory," are used to describe various types of scientific explanations. In this activity, you will construct a mental model that illustrates common descent.

Materials and Equipment

For each student:

- Notebook
- Pencil

Modification of Activity 4*: Investigating Common Descent: Formulating Explanations and Models* from Chapter 6 of the National Academy of Sciences Publication "Teaching About Evolution and the Nature of Science."

For each group of three or four students

- 4 sets of black, white, green, and red paper clips, each set with 35 paper clips. The 4 colors may vary

Procedure:

Part 1

1. Review Table 1, Characteristics of Apes and Humans and Figure 1, Morphological Tree.
2. Find the part of the morphological tree that shows the relationships between gorillas, chimpanzees, and humans. Notice that there are no lines showing relationships. Work with partners and develop three hypotheses to explain how these organisms are related.
3. On a sheet of notebook paper, make a diagram of your hypotheses by drawing lines from Point A to each of the three organisms (G = gorilla, C = chimpanzee, H = human, A = common ancestor).

   Record you final three "hypotheses" below.

Part 2

1. Working in groups of four, "synthesize" strands of DNA according to the following specifications. Each different color of paper clip represents one of the four bases of DNA. For example:

black = adenine (A)	green = guanine (G)
white = thymine (T)	red = cytosine (C)

   Use the above or any other appropriate combination of 4 colors. The colors used do not need to be the same for all groups.
2. Synthesize DNA strands by connecting paper clips in the proper sequence according to specifications listed for each group member. When you have completed the synthesis, attach a label to Position 1 and lay your strands on the table with Position 1 on the left.
   - *Group member 1*

     Synthesize a strand of DNA that has the following sequence:

     Position 1 Position 20

     A-G-G-C-A-T-A-A-A-C-C-A-A-C-C-G-A-T-T-A

Label this strand "human DNA." This strand represents a small section of the gene that codes for human hemoglobin protein.

- *Group member 2*

  Synthesize a strand of DNA that has the following sequence:

  Position 1 Position 20

  A-G-G-C-C-C-C-T-T-C-C-A-A-C-C-G-A-T-T-A

  Label this strand "chimpanzee DNA." This strand represents a small section of the gene that codes for chimpanzee hemoglobin protein.

- *Group member 3*

  Synthesize a strand of DNA that has the following sequence:

  Position 1 Position 20

  A-G-G-C-C-C-C-T-T-C-C-A-A-C-C-A-G-G-C-C

  Label this strand "gorilla DNA." This strand represents a small section of the gene that codes for gorilla hemoglobin protein.

- *Group member 4*

  Synthesize a strand of DNA that has the following sequence:

  Position 1 Position 20

  A-G-G-C-C-G-G-C-T-C-C-A-A-C-C-A-G-G-C-C

Label this strand "common ancestor DNA" and set it aside. Do not examine it yet. You will use this strand later in the activity. Since you are developing a model, just think of this DNA as being found in an organism that does not yet exist!

This DNA strand represents a small section of the gene that codes for the hemoglobin protein of a common ancestor of the gorilla, chimpanzee, and human.

3. Compare the human DNA to the chimpanzee DNA by matching the strands base by base (paper clip by paper clip).

4. Count the number of bases that are not the same. Record the data in a table. Repeat these steps with the human DNA and the gorilla DNA.

Hybridization data for human DNA

Human DNA compared to:	Number of matches	Unmatched bases
Chimpanzee DNA		
Gorilla DNA		

Data for common ancestor DNA

Common ancestor DNA compared to:	Number of matches	Unmatched bases
Human DNA		
Chimpanzee DNA		
Gorilla DNA		

Analysis

1. How do the gorilla DNA and the chimpanzee DNA compare with the human DNA?

2. What do these data suggest about the relationship between humans, gorillas, and chimpanzees?

3. Do the data support any of your hypotheses? Why or why not?

4. What kinds of data might provide additional support for your hypotheses?

Part 3

Biologists have determined that some mutations in DNA occur at a regular rate. They can use this rate as a "molecular clock" to predict when two organisms began to separate from a common ancestor. Most evolutionary biologists agree that humans, gorillas, and chimpanzees shared a common ancestor at one point in their evolutionary history. They disagree, however, on the specific relationships among these three species. In this part of the activity, you will use data from your paper-clip model to evaluate different hypotheses about the relationships between humans, gorillas, and chimpanzees.

Evolutionary biologists often disagree about the rate of evolutionary change and about the exact nature of speciation and divergence. Reinforce the idea that models can be useful tools for testing hypotheses.

Procedure:

1. Assume that the common ancestor DNA synthesized in Part II represents a section of the hemoglobin gene of a hypothetical common ancestor. Compare this common ancestor DNA to all three samples of DNA (gorilla, human, and chimpanzee), one sample at a time. Record the data in a table.

The data for the comparisons are as follows: human DNA, 10 unmatched bases; chimpanzee DNA, 8 unmatched bases; gorilla DNA, 3 unmatched bases.

Analysis

1. Which DNA is most similar to the common-ancestor DNA?

2. Which two of the DNA sequences were most similar in the way that they compared to the common-ancestor DNA?

3. Which of the hypotheses developed in Part I do your data best support?

4. Do your findings prove that this hypothesis is correct? Why or why not?

5. Based on the hypothesis that your data best supported, which of the following statements is most accurate? Explain your answer in a short paragraph.
   (a) Humans and apes have a common ancestor.
   (b) Humans evolved from apes.

6. According to all the data collected, which of the following statements is most accurate? Explain your answer in a short paragraph.
   (a) Chimpanzees and humans have a common ancestor.
   (b) Chimpanzees are the direct ancestors of humans.

7. A comparison of many more DNA sequences indicates that human DNA and chimpanzee DNA are 98.8 percent identical. What parts of your data support this result?

8. What methods of science did you use in this activity?

Table 1 Characteristics of Apes and Humans		
Characteristics	**Apes**	**Humans**
Posture	Bent over or quadrupedal "knuckle-walking" common	Upright or bipedal
Leg and arm length	Arms longer than legs; arms adapted for swinging, usually among trees	Legs usually longer than arms; legs adapted for striding
Feet	Low arches; opposable big toes, capable of grasping	High arches; big toes in line with other toes; adapted for walking
Teeth	Prominent teeth; large gaps between canines and nearby teeth	Reduced teeth; gaps reduced or absent
Skull	Bent forward from spinal column; rugged surface; prominent brow ridges	Held upright on spinal column; smooth surface
Face	Sloping; jaws jut out; wide nasal opening	Vertical profile; distinct chin; narrow nasal opening
Brain size	80 to 705 cm3 (living species)	2400 to 2000 cm3 (fossil to present)
Age at puberty	Usually 10 to 13 years	Usually 13 years or older
Breeding season	Estrus at various times	Continual

Figure 1.
Evolutionary relationships among organisms derived from comparison of skeletons and other characteristics